Product Engineering

Program Manager: Ram D Sriram
Total FTE: 17.4
Total Funding: $1,533,000

Goal

Develop information protocols for interoperability of computer-aided design and product engineering systems, which provide a basis for future standards.

Program Objectives

FY2000

Take working draft of ISO 10303 (informally known as the Standard for the Exchange of Product model data - STEP) parameterization and constraints of geometric schema to ISO as ISO/CD 10303-108.

Systems Integration for Manufacturing Applications (SIMA) Parametrics Project

Make US industry more efficient by providing an enhanced standard for computer aided design (CAD) data exchange. This will save significant non-value-added CAD operator time that can be employed for more productive purposes.

FY2000

Develop assembly-based representations that include tolerance specifications.

Design for Tolerancing of Electro-mechanical Assemblies

Advance tolerancing decisions to the earliest possible stages of design, and address the appropriate synergistic use of available methods and best practices for tolerance analysis and synthesis at successive stages of design.

FY2000

Develop specifications for the solid interchange format for layered manufacturing (SIF-LM).

Solid Interchange Format for Layered Manufacturing (SIF-LM)

Improve current data transfer capabilities from computer-aided design (CAD) systems to rapid prototyping (RP) systems through development of a proposed alternative to the existing CAD-RP interface.

FY2001

Demonstrate parametrics interchange between CAD systems.

FY2001

Demonstrate SIF-LM in collaboration with industry and university partners

FY2001

Generate design ontologies as a first step toward the science of manufacturing system integration.

FY2001

Implement prototypes that demonstrate interoperability between immersive CAD and traditional CAD systems.

Traditional CAD to Immersive CAD Interfaces

Develop the appropriate interfaces and standards that will be used by industry for the integration and interoperability of traditional and immersive CAD systems.

FY2001

Develop specifications for design knowledge interchange.

The NIST Design Repository

Develop an information modeling framework to support the creation of design repositories, the next generation of design database. The outcome of this work will be the implementation of a prototype design repository tool suite that addresses the objectives laid out below. This tool suite will consist of web-based interfaces, a client/server-based architecture, and example design repositories to demonstrate the functionality and utility of the design repository concept.

FY2002

Demonstrate interface specifications for interoperability of knowledge systems.

Knowledge-based System Interoperability

Identify the knowledge representation needs for next-generation product development systems, and develop a generic core representation for product development knowledge on which future systems can be built. This project seeks to address potential interoperability problems proactively, rather than reactively, by providing this core as a foundation for improved interoperability among software tools in the future.

FY2003

Develop interface specifications and prototypes for integration of CAD systems and manufacturing software.

FY2004

Develop interface specifications and prototypes for knowledge-level interoperability of design information.

Customer Needs

Introduction: Design of complex engineering systems is increasingly becoming a collaborative task among designers or design teams that are physically, geographically, and temporally distributed. The complexity of modern products means that a single designer or design team can no longer manage the complete product development effort. Hence, companies are increasingly staffing only their core competencies in-house and depending on other firms to provide the complementary design knowledge and design effort needed for a complete product. Designers are no longer merely exchanging geometric data, but more general knowledge about design and the product development process, including specifications, design rules, constraints, and rationale. Furthermore, this exchange of knowledge often crosses corporate boundaries. As design becomes increasingly knowledge-intensive and collaborative, the need for computational frameworks to support product engineering in industry becomes more critical.

Needs Assessment: To assess the importance of various computer aided design (CAD) /computer aided engineering (CAE) technologies to industry, as well as to identify specific interoperability needs, several workshops have been sponsored by NIST: STEP-based Solid Interchange Format Workshop (November 1996), NIST Design Repository Workshop (November, 1996), Network-Centric CAD: A Research Planning Workshop (December, 1996), Tools and Technologies for Distributed and Collaborative Design (August, 1997), Assembly Level Tolerancing: Standards and Implementation Issues Workshop (April 1997), 1997 Knowledge-based Systems Interoperability Workshop (November, 1997), Intelligent and Distributed CAD (July, 1998), Design Manufacturing Integration Workshop (November 1998), and Virtual Assembly Technology Meeting (March 1999). Each of these workshops were attended by dozens of researchers from large and small businesses, government, and academia, representing the country's leading engineering organizations, software vendors, and academic institutions. In addition to these workshops, a number of other supporting documents has been researched that identify critical industry needs in this area.

Impacts: The ultimate technical benefits of the Product Engineering Program include an improved infrastructure for using and exchanging design knowledge, and for integration of information across time, space and engineering domains. These benefits will translate to broad-based economic benefits through accelerated product development, reduced direct design costs, and improved product quality. According to a Daratech report, the current mechanical CAD industry is approximately a $4 B industry. With new emerging areas, such as immersive CAD and knowledge-based CAD, this is likely to increase considerably in the next decade. One major problem with the emergence of various heterogeneous CAD systems is the lack of interoperability among these systems. A recent study (http://www.rti.org/publications/cer/7007-3-auto.pdf) estimated that imperfect interoperability imposes costs of at least $1 B per year on the U.S. automotive supply chain alone; other industries may have similar costs associated with lack of interoperability among CAD/CAE/CAM (computer aided manufacturing) applications. This has significant implications for the costs at all design stages. This, in turn, has an enormous impact on the overall product cost, as decisions made during the design stage determine 70 % of the product's cost over its life. When a jet engine costs $2 B to develop (as the General Electric GE 90 for the Boeing 777 did) or a new model automobile costs between $3 B to $6 B (Ford), the potential impact of the Product Engineering Program is substantial. This will translate to benefits for consumers through lower costs, improved quality and faster introduction of new technology into the marketplace. They will benefit U.S. industry through increased profit due to lower costs, and through improving market share and sales volume of U.S. products domestically and abroad.

Industry input (through the workshops mentioned above) has led to specific quantitative estimates of the impact technologies in this area can provide. The following issues have been emphasized in these workshops:

1. Increased competitiveness of U.S. industry by reducing design and production costs as well as product development time. Specific targets include: reduction in direct design costs of 10 % to 30 %, reduction of time-to-market of 25 % to 75 %, and reduction of defect rates and engineering change requests of 23 % to 70 %. The range in values reflects the variances from one industry to another on the realistic degree of improvement.

2. Enhanced knowledge-aided electronic commerce for supporting intelligent and distributed design. Access to distributed design databases and seamless interoperability among CAD systems would result in an efficient electronic commerce framework.

3. Increased support of collaboration among distributed designers, design teams, and companies. The benefits should permit designers to delay detailed design longer and permit members of distributed design teams to take control of portions of the design and allow review by remote colleagues. This will allow team members to be used most effectively.

4. Increased capture and linkage of design information across various stages of the product life cycle. Benefits will include improved reuse of design information across product families, and more rapid redesign efforts. In addition to reducing development time, improved feedback of knowledge into subsequent design processes will increase quality and reduce warranty and repair costs later on.

Technical Approach

The Product Engineering Program focuses on the key issues that are emerging from a collaborative product development paradigm. Specifically, the primary needs for the next generation of CAD/CAM/CAE software systems are interoperability among software tools, collaboration among distributed designers and design teams, integration of data and knowledge across a product development cycle (from design, to analysis, to manufacturing and beyond), as well as knowledge capture, exchange and reuse. The research and development (R&D) efforts within this program, ranging from specification and standards development to technology development and prototype implementation, strive to provide the foundation that will support the creation of next-generation product development tools, thereby increasing the efficiency, effectiveness, capability, and productivity of U. S. industry in the 21st century.

STEP (ISO 10303, informally known as the Standard for the Exchange of Product Model Data) is capable of successfully transferring product shape models in terms of their geometry and topology. However, modern CAD systems generate models containing additional information concerned with parameterization, constraints and features. This permits a shape model to be edited or optimized according to the designer's original notions of freedom and restraint in the design. It is highly desirable that STEP is extended to capture and transmit this additional information, to make it easier to edit models following a transfer. The SIMA Parametrics project is currently working towards this goal, with the aim of saving the time currently spent in trying to regenerate information that was present in the transmitted model but lost in translation into the STEP format. The result will be improved efficiency in the product development cycle.

One of the gaps in current CAD tools is a lack of standardized representations for some types of assembly data, such as inter-part relationships, mating features, and others. Such representations will enable more efficient and cost-effective integration of assembly analysis tools, and more accurate translations of data. It is expected that work on assembly modeling and representation will provide input to the incorporation of assembly information content into STEP. Work in this area also includes the development of an assembly design environment architecture that supports extensions to current CAD assembly functionality using virtual reality, and provides mechanisms to integrate or interface other CAD/CAM applications. Proceeding in conjunction with this work is an effort on the development of methods and best practices for tolerance analysis and synthesis. The aim of this work is to advance the use of tolerancing information to the earliest possible stages of design, in contrast to the traditional approach of performing tolerance synthesis after design. This, in turn, requires effective representation of tolerancing information during various stages of design such as during assembly modeling.

Another approach to integrating design with activities that traditionally follow design is work towards the integration of design and process planning. The objective of this research is to develop specifications and interfaces to enable design and process planning integration at the conceptual design stage, to provide the ability to perform conceptual process planning. Tools that make use of process planning information at early stages of design will allow estimates of cost and performance from designs that are not completely specified. This information can then be used to guide evaluation of design alternatives. Other related projects include development of a solid interchange format for layered manufacturing (SIF-LM) and interface specifications between design and manufacturing simulation.

In the area of knowledge capture and reuse, one project within this program is working toward the development of an information modeling framework to support the creation of design repositories, the next generation of design databases that would facilitate knowledge-aided e-commerce. This project is driven by industry needs for technology to support the increasing role of knowledge-based design, including the representation, capture, sharing, and reuse of corporate design knowledge. Ongoing work includes developing a design modeling language for representing design artifact knowledge, implementing interfaces for creating and browsing artifact repositories, and creating prototype design repositories to demonstrate these technologies.

Overall Technical Approach: The IMES (Initial Manufacturing Exchange Specification) methodology is followed closely in addressing the above issues. This essentially involves organizing workshops to determine industry needs and requirements; developing interface specifications; and participating in national and international standards committees. We work closely with academia, industry, and other government agencies in achieving our goals. These collaborative efforts result in considerable savings to all participants.

NIST and MEL Role: NIST's neutral position makes it an ideal organization for conducting research in design representations, leading to robust interoperability standards. This was iterated by many industry attendees at our workshops, who felt that NIST is the ideal organization for developing interface specifications and knowledge repositories. Over 80 % of the staff working in this area hold doctoral degrees in engineering and computer science. Our close working relationship with the NIST Advanced Technology Program and the NIST Small Business Innovation Research Program provides additional opportunities for industry interaction.

Standards Participation

- American Society of Mechanical Engineers (ASME) Y14.5 Dimensioning and Tolerancing (GD&T): Participate in committee activities.
- American Society of Mechanical Engineers (ASME) Y14.5.1 Mathematical Definition of Dimensioning and Tolerancing Principles: Participate in committee activities.
- ISO TC184/SC4 Industrial Automation and systems integration, Industrial data: Participate in the establishment of a Rapid Prototyping Interest Group in ISO TC184/SC4
- ISO TC184/SC4/WG12 Industrial Data, Common Resources: Chair the Parametrics Group
- ISO TC213/WG10 Dimensional and geometrical product specifications and verification, Dimensional and geometrical product specifications and verification: Participate in committee activities.
- ISO TC213/WG13 Dimensional and geometrical product specifications and verification, Statistical tolerancing of mechanical parts: Play a liaison role in the harmonization of STEP tolerancing.
- OMG Manufacturing Domain Task Force (Mfg DTF): Participate in OMG's Manufacturing Domain Task Force. This organization is responsible for setting the overarching strategy for the working groups that comprise the task force. Specific activities include: developing a Request for Information (RFI) for Integrated Product and Process Engineering.

Accomplishments

- September FY1999 Developed initial version of core product representation for next generation CAD systems.
- September FY1999 Added considerable knowledge to the Design Repository.
- September FY1999 Helped form a consortium for virtual assembly at WSU.
- September FY1998 Held industry workshops to identify leading-edge technologies and key technology gaps: Design/Manufacturing Integration: Standards and Implementation Issues (1998), and NIST/ATP Workshop on Intelligent and Distributed CAD (1998).
- September FY1998 Surveyed manufacturing process planning and conceptual design methodologies in the literature. Developed a draft activity model for conceptual process planning. Developed a prototype conceptual gearbox design system and a prototype conceptual process planning system based on ICAD.
- September FY1998 Developed information models for representation of design artifact information. Developed web-based interfaces for creation, editing and browsing of design repositories. One prototype repository has been completed and others are under development. (1997-1998)
- September FY1998 Contributed to standards development activities, including a Working Draft of a new STEP resource (Parameterization and Constraints for Explicit Geometric Product Models), a Technical Corrigendum for STEP Part 203, and a technical report on Long-Term Parametrics. Attended numerous ISO standards meetings. (1997-1998)
- September FY1998 Prepared an initial EXPRESS-G data planning model for the proposed STEP-based Solid Interchange Format. Prepared a requirements document to identify needs for representation of layered manufacturing data.(1997-1998)
- September FY1998 Surveyed manufacturing process planning and conceptual design methodologies in the literature. Developed a draft activity model for conceptual process planning. Developed a prototype conceptual gearbox design system and a prototype conceptual process planning system based on ICAD.
- September FY1998 Developed initial specification for the Open Assembly Design Environment (OpenADE), with the goal of developing interface specifications for various assembly related tasks. Completed implementation of prototype OpenADE system that includes integration of several CAD and virtual reality (VR)-based applications.

- September FY1998 Performed case study with an industry partner to identify small-business needs in the area of Internet-based delivery of CAD/CAM services.
- September FY1998 Acted as a funding agent for Defense Advanced Research Projects Agency's (DARPA) Rapid Design, Exploration and Optimization (RaDEO) Program, which led to an increased awareness and utilization of STEP standards in the industry.
- September FY1998 Developed and tested methods to augment conventional numerical optimization with artificial intelligence to successfully optimize complex engineering designs with existing simulators.
- September FY1997 Held industry workshops to identify leading-edge technologies, key technology gaps, and interoperability standards needs: Knowledge-Based Systems Interoperability: Standards and Implementation Issues (1997), Tools and Technologies for Collaborative and Distributed Design (1997), Measurement and Standards Issues in Rapid Prototyping (1997), and NIST Workshop on Assembly-Level Tolerancing (1997).
- September FY1996 Held industry workshops to identify leading-edge technologies, key technology gaps, and interoperability standards needs: Knowledge-Based Systems Interoperability: Network-Centric CAD: A Research Planning Workshop (1996), STEP-Based Solid Interchange Format Workshop (1996), and NIST Design Repository Workshop (1996).